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Introduction

As is the case in several post-industrial societies,¹–⁷ spatial health inequalities have increased in France since the 1990s.⁸,⁹ Urban–rural and intra-urban disparities have widened, reflecting major changes in the spatial distribution of mortality.¹⁰ Static approaches have shown the spatial disparities to be markedly associated with socio-economic deprivation,¹⁰ with an increasing gradient during the 1990s.¹¹

Among the factors that may explain a widening mortality gap, the contribution of demographic changes (population increase or decrease and population mobility) has been cited but little investigated.¹² The population increase or decrease in a specific area is, however, a marker of its social, economic, cultural and environmental dynamics that is not automatically incorporated in conventional measures of deprivation.¹³ Population change with underlying socially selective migration¹²,¹⁴–¹⁸ and residential instability¹⁹ reflects the local dynamics in terms of employment, services, housing and other parameters, which may influence local change in mortality.

The association between mortality and demographic change has been investigated in the United Kingdom since the nineteenth century.²⁰,²¹ The migration of thousands of workers from rural to industrial urban areas was associated with a deterioration in mortality in urban areas. Since then, the association has reversed: a population increase is generally associated with a decrease in the mortality rate. More specifically, positive population growth is associated with a marked mortality reduction, whereas only a tiny decrease in mortality has been observed in declining populations in the United Kingdom and Ireland.²² The negative association between mortality and population growth was stronger for men than for women²³–²⁶ and weaker for specific causes of death (cancer, alcohol, mental disorder, etc.).²⁴,²⁵ Moreover, premature mortality seems to be more related to population decline than mortality after 65 years of age.²⁵

Although affluent and deprived areas show different patterns in terms of mortality trends²⁷,²⁸, the association between population change and mortality remains significant after controlling for deprivation.³,¹³,²³,²⁵ The association between population changes and mortality seems to be specific in terms of time and place,²⁴ and also to depend on the scale of the analysis and the definition of deprivation used.²,²³,²⁹,³⁰ However, most of the studies have only taken one time interval into consideration and ignored long-term population change and inflections of population change.

With regard to the spatial distribution of mortality in France, the purpose of this area-based study was to investigate the association between the change in relative mortality and population growth rate in various spatial and deprivation-level areas from 1975 to 2006. Do demographic changes constitute a good marker of major social change in an area and enable enhanced understanding of the widening gap in spatial health inequalities? This approach is particularly necessary in view of the recent changes in the migration process (rural depopulation, urban sprawl, deindustrialization, urban renovation). The association is to be modulated in terms of the degree of urbanization and deprivation, which may also contribute to interpreting the outcomes.

Methods

Spatial scale

Two scales were considered. The commune (smallest administrative unit) scale (36,000 units) was used in the first part of the study. The fine scale enabled the mortality differentials related to population...
The expected number of deaths in canton $i$ and separately for men and women for premature mortality (less than 65 years). To analyse relative changes, independently of the general decline in mortality over the period, the reference national mortality rates used to estimate the SMRs were specific to each canton (3700 units) was considered the spatial unit to evaluate the association between population change and change in relative mortality.

Mortality data

The mortality data were derived from the Inserm-CepiDc database for mainland France. Deaths were grouped in 5-year periods, centred on the census years (1975, 1982, 1990, 1999 and 2006, defined as $p_t$) to ensure accurate denominators. Standardized mortality ratios (SMR) for all causes of death were calculated for both genders and separately for men and women for premature mortality (less than 65 years). To analyse relative changes, independently of the general decline in mortality over the period, the reference national mortality rates used to estimate the SMRs were specific to each period. The expected number of deaths in canton $i$ in year $p_t$ was defined as $E_{pt}^{(i)}$. Exact 95% Poisson confidence intervals were calculated.

Cause-specific SMRs were calculated for the main causes of death (cf. table S1 for ICD codes).

Demographic data

The population data were obtained from the National Institute of Statistics and Economic Studies (INSEE) and derived from the 1975, 1982, 1990, 1999 and 2006 censuses.

The population growth rate was calculated for each between-census interval as the compound annual population growth rate (CAPGR):

$$\text{CAPGR}^{p_{t+1},p_t} = \sqrt[1/n]{\frac{\text{Pop}(p_{t+1})}{\text{Pop}(p_t)}} - 1,$$

in which $n$ is equal to $p_{t+1} - p_t$, and $\text{Pop}(p_t)$ is the population count in $p_t$.

Demographic change typology

To take into account the anteriority of the urbanization process, initiated and amplified from the 1960s in France, demographic changes were analysed from 1962 to 2006. The urbanization process was characterized by a phase of intense rural exodus until the 1990s, followed by major inter-urban movements after the 1990s.

The communes were categorized using the three groups defined by the National Institute of Statistics and Economic Studies (cf. Supplementary material):

–Urban core and inner suburbs
–Peri-urban
–Rural

Degree of urbanisation (ZAU90)

The communes were categorized using the three groups defined by the National Institute of Statistics and Economic Studies (INSEE) and derived from the 1975, 1982, 1990, 1999 and 2006 censuses.

Measurement of the association between the change in relative mortality and population change

The association was measured using a generalized estimating equation over-dispersed Poisson regression. The change in SMR was addressed as correlated repeated measurements of the same canton for two consecutive census periods. The model was defined as follows:

$$O_{pt}^{(i)} \propto P(X^{(i)}_{pt})$$

$$\log(X^{(i)}_{pt}) = \log(E_{pt}^{(i)}) + \alpha_0 + \beta_0 \cdot \text{CAPGR}^{p_{t+1},p_t} + \beta_1 \cdot I(p_{t+1})(u) \cdot \text{CAPGR}^{p_{t+1},p_t}$$

Where $u = p_t$ and, $p_{t+1}$ for the canton $i$, and $I(p_{t+1})(u)$ is the indicator variable of the second census period $p_{t+1}$.

Parameter $(\alpha_0, \beta_0)$ adjusted the mortality for the two census periods on the CAPGR. Parameter $\beta_1$ captured the variability of the mortality difference between the two periods explained by the CAPGR because the difference between the two-period log measurements for canton $i$ yield the following ratio:

$$\frac{\lambda_{p_{t+1}}^{(i)}}{E_{p_{t+1}}} = \exp(\beta_1 \cdot \text{CAPGR}^{p_{t+1},p_t}) \approx 1 + \beta_1 \cdot \text{CAPGR}^{p_{t+1},p_t}$$

For a 1% increase in CAPGR ($\approx 8.2\%$ for 8 years) between $p_t$ and $p_{t+1}$, the SMR of canton $i$ varied by $\beta_1\%$. This result is based on linear approximation of the exponential function in the neighbourhood of 0: $\exp(\beta_1 \cdot \text{CAPGR}) - 1 \approx \beta_1 \cdot \text{CAPGR}$.

Results

Demographic dynamics summary

During the 1975–2006 period, the population of mainland France increased from 50 to nearly 64 million people, with immigration contributing 15–20% of the population growth. Overall, the communes whose population declined and the most deprived in terms of the deprivation index FDep90 were located in the north and centre of the country (figure 1), in the centre of Brittany, and in the east of France (Lorraine). The communes were mainly urban areas in the old industrial basin (north-eastern arc) or rural zones located in the interstices of several urban areas. In consequence, the communes located along departmental boundaries were over-represented in this category. Population decline and deprivation were also scattered through much of the country in highly densely populated suburbs characterized by unemployment and social segregation.31

The least deprived communes presenting population decline were mainly Parisian arrondissements (districts) and suburbs of medium deprivation index (FDep90)

The extreme population weighted quintiles (1st and 5th) of the deprivation index FDep9010,11 were considered in order to control the association between population change and change in relative mortality.

The deprivation index, FDep90 was defined as the first component of a principal component analysis including the following four variables: median household income, percentage high school graduates in the population aged 15 years and older, percentage of blue-collar workers, and unemployment rate in 1990.

The communes consisting of less than 50 households were excluded due to the absence of median household income information for small areas. In all, 30,500 communes were included in the mortality and deprivation analysis.

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to large urban centres, in which, historically, the wealthiest people have tended to congregate.

The least deprived communes presenting population increase were Parisian arrondissements and some of the western suburbs of Paris. Several city centres with a population of more than 100,000 people were included in this category. Some suburbs of the main urban areas in the east and south-west and along the urban network extending from Paris to the urban areas of the Atlantic coast were also included.

The most deprived communes whose population had increased were mainly located in the hinterland of the Atlantic and Mediterranean littoral zones and consisted in rural or peri-urban areas that benefited from the economic activity of the nearest wealthy urban area. The boundary communes of the old industrial basin also experienced a population increase. The cross-border German, Belgian and Swiss urban areas attracted people to the region.

**Association between change in premature-death SMR and population change by deprivation quintile**

Generally, the SMR increased when the commune population declined and decreased when the commune population strongly increased (figure 2). The time-course gradient was bordered by the DEC category with higher and increasing SMR, and the INC2 category with lower and decreasing SMR. The changes in SMR differentials were larger between population change categories for premature mortality than for all-age mortality (results not shown). The remainder of the article focuses on premature mortality.

Although the mortality differentials were already large in 1975, the DEC category SMR increased by more than 10%, whereas the INC2 category decreased by nearly the same percentage. The SMR increased over the entire period for the INC1 and INC/DEC categories. The DEC/INC category showed a slight reduction in premature SMR in the last period following an increase from 1975 to 1999.

The least deprived communes generally had lower mortality than the most deprived communes (figure 2). Irrespective of the period and deprivation quintile, marked mortality differentials were observed by population change typology. However, the differences were less marked for the least deprived quintiles than for the most deprived quintiles. Over the entire period, in the least deprived quintile, the differences between the DEC and INC2 categories were less than 20%, whereas the differential increased in the most deprived quintile: in 2006, the differential between the DEC and INC2 categories exceeded 25%. The SMR decreased similarly in each category of the least deprived quintile, but the decrease was steeper for the population-decline category, with decreases ranging from 15% to 20%.

In the most deprived quintile, the population change category was associated with the amplitude of the SMR increase. The SMR of the population-increase categories slightly increased over the entire period, whereas the SMR of the declining category sharply increased after 1990. Overall, the widening inequalities in the most deprived communes were reflected in the population-change categories.

**Association between change in premature-death SMR and population change by degree of urbanization**

Premature SMR changes showed different profiles depending on the type of area (figure 3). For city centres and inner suburbs, changes in the premature SMR were associated with the population dynamic: the SMR slightly declined for the INC2 category. However, the SMR increased for all the other categories.

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**Association between change in premature-death cause-specific SMR and CAPGR**

From 1975 to 2006, the average CAPGR was 0.5%, with a minimum of −2.1% and a maximum of 10.7% (table S3).
The association was negative and significant overall for all-cause mortality, violent deaths and alcohol abuse and chronic liver disease mortality for both genders and particularly for men (table 1). The association was noticeably stronger for alcohol abuse and chronic liver disease. Although the association was negative for several causes (all cancers, aero-digestive cancer, cerebrovascular disease, infant mortality), it was not significant for some periods. The association was stronger for the 1990–99 period. The association was non-significant or weakly significant ($0.001 < P < 0.05$) for ischaemic heart disease, lung cancer, colorectal cancer, bladder cancer, breast cancer and prostate cancer.

**Discussion**

The findings of this study suggest an association between the change in relative mortality and population change. Although mortality sharply decreased from 1975 to 2006, absolute inequalities between the area socio-demographic categories widened except in the least deprived areas (table S2). The SMRs showed that relative mortality deteriorated in areas experiencing population decline and improved in areas whose population grew substantially. In addition to being modulated by the degree of deprivation and urbanization, the association was stronger for premature mortality than for all-age mortality and was more pronounced for men than for women and for some causes of death (violent deaths, alcohol-related deaths). The association was also observed without any lag time.

The deprived areas in population decline experienced dramatic relative mortality increases, confirming previous results.\(^{23,32}\) The areas consisted of both rural and urban areas. The former were remote from economic centres, located along regional or departmental boundaries (figure 1), and may have entered a downward developmental spiral under the effects of rural–urban migration: loss of attractiveness, reduced economic activity and progressive closure of the services supplied to the most socially disadvantaged captive populations. The urban areas accumulated economic difficulties and social disorders. This was the case for declining industrial zones in the north-eastern arc and densely populated deprived suburbs in the biggest cities.

In contrast, in the least deprived areas, population-decline zones did not exhibit a relative deterioration in relative mortality; after 1990, those areas showed marked improvement in their relative health status. The zones consisted of the wealthy arrondissements of Paris and inner suburbs, where the phase of urban sprawl in 1990 was associated with social selection of the population in the inner city. This occurred at the time of city-centre modernization projects and a gentrification process.

The deprived areas whose population increased exhibited the national average mortality. The areas consisted of newly residential areas under the influence of an urban core or a revival of tourism (figure 1). In some cases, there may have been an influx of a wealthier population and protection by factors influencing mortality.\(^{33,34}\) However, the increase in real estate prices has induced socio-economic selection in city centre areas, as was the case in the Paris area where the peri-urban areas distant from the city centre are characterized by sizable populations at the bottom of the social scale.\(^{35}\)

Since the 1980s, the peri-urban areas have been characterised by the settlement of middle-class employees working in neighbouring urban centres. By the same mechanism, this population may have been healthier than the initial sedentary population and thus may have positively influenced mortality indicators.\(^{28}\) However, the increase in real estate prices has induced socio-economic selection in city centre areas, as was the case in the Paris area where the peri-urban areas distant from the city centre are characterized by sizable populations at the bottom of the social scale.\(^{35}\)

The analysis by gender and age suggests a stronger relationship for men, which is consistent with previous findings.\(^{23–26}\) The cause-specific outcomes showed a negative association for almost

**Figure 2** Change in premature SMR from 1975 to 2006 for different demographic change profiles of the communes by deprivation quintiles - all, least and most deprived
all the causes of deaths and periods, although not all were significant. The causes of death that are generally closely related to socio-economic status—alcohol and violence—were strongly associated with CAPGR. Although previous studies failed to demonstrate a strong significant association between those causes and population change, a Scottish study has shown that alcohol-related and some violent deaths greatly contribute to excess mortality in deprived areas experiencing population decline. The results of the present study suggest an SMR increase for those causes in areas experiencing the same adverse context. If
migrants generally have higher socio-economic status than non-migrants, migrants will be likely to experience a lower risk of alcohol- and violence-related mortality. Hence, the SMR may rise specifically for these causes in the areas left by migrants, whereas SMR may decrease at their place of destination even though no health improvement or degradation has occurred in the sedentary population.

Although some authors have pointed out that changes in deprivation are associated with changes in mortality, those dynamics were not addressed in this study. The socio-territorial characteristics of the communes were determined in 1990, which is likely to have influenced relative mortality changes. However, the deprivation index used showed 0.97 correlation from 1990 to 1999. Further studies need to measure the extent to which deprivation change is associated with mortality change over a longer time period, but the main obstacle remains the lack of data before 1984. In addition, the commune scale does not enable the strong intra-urban disparities to be disentangled. Thus, some of the most extreme situations cannot be observed on that scale.

In the Poisson regression, the association between all-cause relative mortality change and CAPGR remained significant after controlling for deprivation and degree of urbanization (results not shown). The population growth rate, which strictly measures the population change over a period, does not enable population renewal and natural growth to be distinguished. However, the growth rate remained strongly correlated with the net migration rate (from 0.82 to 0.95, depending on the period). Therefore, the growth rate partially evaluates the impact of population renewal on mortality risks.

Further analysis would enable evaluation of the respective weights of population renewal (selection effect) and unmeasured contextual effects that mediate the association with mortality change. It would be necessary to work on an individual scale to measure the mortality level in both the sedentary and migrant populations because the net difference between the health outcomes of people who settle in an area and those they replace (the out-goers) have implications with respect to widening health inequalities.

This exploratory ecological study highlights the relevance of the dynamic approach to mortality inequalities; the dynamic approach constitutes a relevant alternative to studies of shrinking areas. In conclusion, population growth rate is an indirect marker of area-based characteristics, additional to deprivation and the urban–rural context, that are associated with mortality changes.

Supplementary data

Supplementary data are available at EURPUB online.

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Conflicts of interest: None declared.

Key points

- The previous research in several countries reported a negative association between population change and mortality that is stronger for men and people aged less than 65 years.
- Using a 30-year period spatiotemporal approach to mortality inequalities with a precise description of population change profile, the population growth rate was found to be significantly associated with a reduction in relative premature-death mortality.
- The deprivation level and degree of urbanization strongly modulate the association.

References

Comparing health status in Belarus between 2001–10: a novel method using surveys with different response categories

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Background: Two population surveys were conducted in Belarus: The Living Conditions, Lifestyle and Health (LLH) in 2001 (n = 2000) and The Health in Times of Transition (HITT) in 2010 (n = 1800). Each survey included a question on health status. The LLH questionnaire provided a 4-point Verbal Response Scale, but the HITT questionnaire used a 5-point scale. When translated into Russian, only two response categories of these scales had identical wording. These differences made a direct comparison of self-reported health status between 2001 and 2010 difficult. Methods: We conducted a Health Category Response Scale (HCRS) survey in 2010 (n = 570) using a 100ths graduated Visual Analogue Scale (VAS) to understand how the response categories of different scales are perceived by Russian speakers. We implemented the HCRS survey’s data to calculate the weighted health status (WHS) for each of the original surveys and to compare health status in Belarus between 2001 and 2010. Results: The WHS in Belarus showed a small, but statistically significant, improvement of 2.9 points on a 0–100 scale between 2001 and 2010 (56.2 vs. 59.1). Identical response categories were perceived differently on a 4-point and 5-point VAS. The category ‘good’ (‘добрый’) measured ~12 points higher, and the category ‘bad/poor’ (‘плохой’) measured ~16 points lower, on the 4-point compared with the 5-point VAS. Conclusion: Our HCRS survey and novel method enabled a direct comparison of questions with different response options. When applied to the LLH and HITT projects, we concluded that health status in Belarus has improved between 2001 and 2010.

Introduction

Self-reported health status is an important indicator of people’s actual health.¹,² Individuals can describe their current health according to how they feel, and self-reported health status has proved to be a strong predictor of mortality, morbidity and health care utilization.¹,³ Approved measures of subjective health are established in population health and lifestyle surveys¹,² and in